Military Aircraft

RCS Simulation

J. Ritter (Jan.Ritter@eads.com)

MATRIX 2005 workshop (NATO SET-069)

10.-12. May 2005, Oberammergau, Germany

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 MAY 2005	**N/A**	**-**

4. TITLE AND SUBTITLE	
RCS Simulation	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **EADS Deutschland GmbH Military Aircraft MT67 Signature Technology Huenefildstrasse 1-5 D-28199 Bremen GERMANY**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM202152., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**36**	

Standard Form 298 (Rev. 8-98)
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Overview

- Introduction
- Methods,Tools for mm-wave applications
- Examples
- Further requirements / developments

Introduction

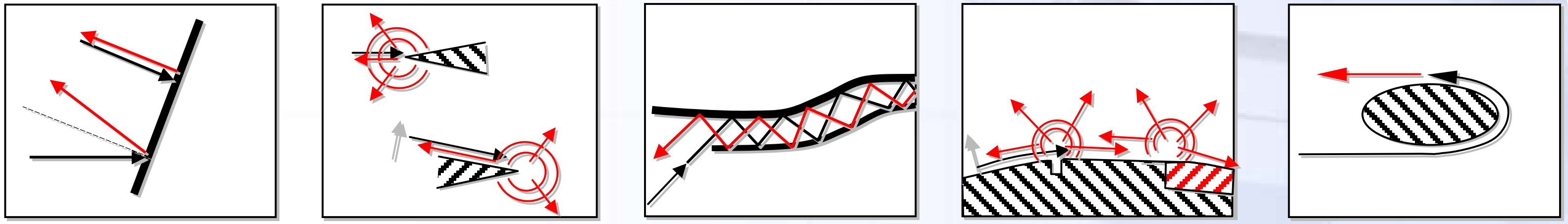
- RCS simulation requirements for Millimeter-Wave applications
  - **Accuracy:** small details (antennas, etc.) important in certain recognition / identification applications
    - Hybridisation of methods
  - **Speed:** algorithms should not scale strongly with frequency
    - Fast algorithms, new Aproaches
    - Geometry representations
  - **Flexibility:** Many configurations (A/C: store config.) to be considered, Moving parts to be considered
    - Flexible handling of Geometry
    - Parametrisation of Geometry

Methods for RCS simulations

- Fundamental subdivision between ***full-wave*** and ***asymptotic*** approach.

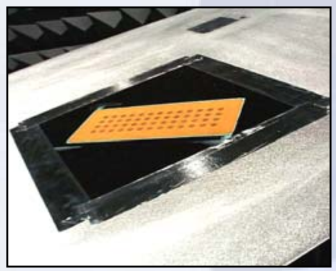
- **Full wave** („low frequency techniques“): Solution of Maxwell‘s equations

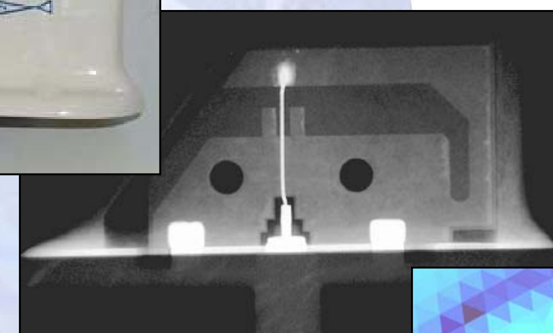
- **Asymptotic** („high frequency techniques“): Approximation of target backscattering by a number of independent effects

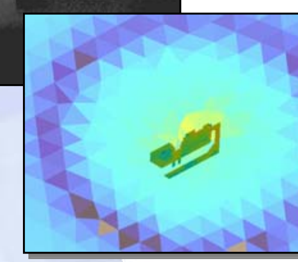


Methods, Hybridisation

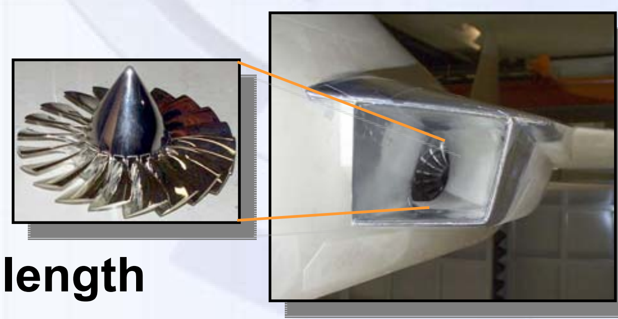
- Complex details (Antennas, cavities, etc.) need „full-wave“ treatment. Examples:
  - **Antennas**







  - **Cavities, inlets**



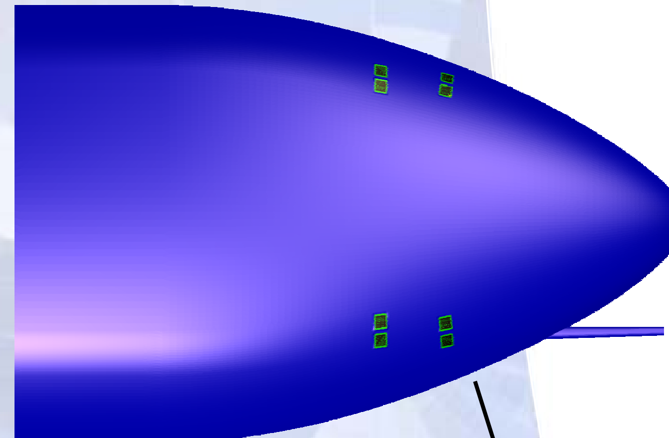
  - **Details of the size of the wavelength**

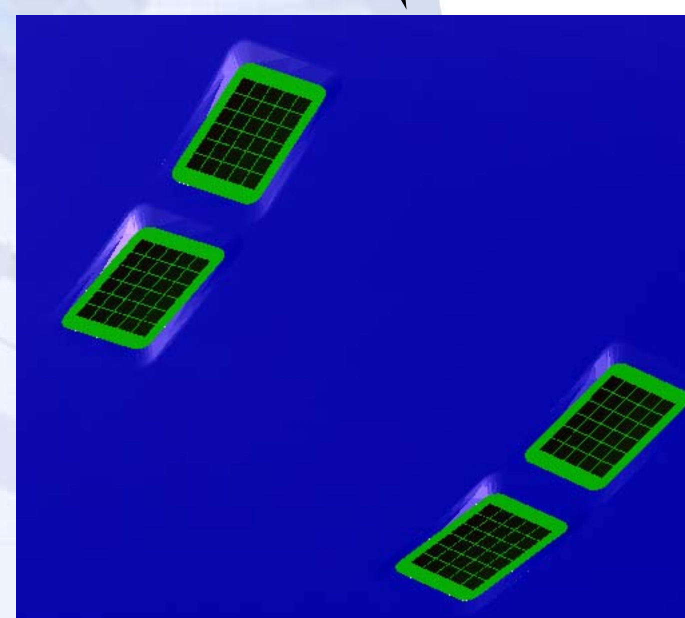
Methods, Hybridisation

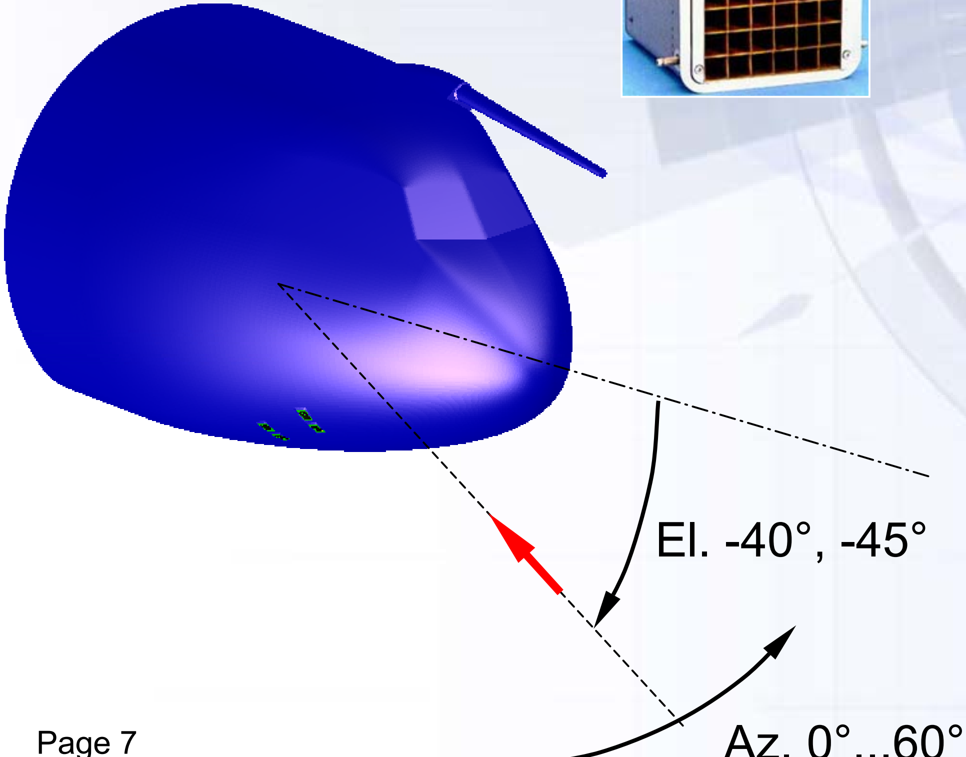
- **Full-Wave methods in use**
  - Multilevel Fast Multipole Algorithm accelerated Method of Moments (MLFMA)
  - Finite Difference (FD) Techniques
  - Modal formulations
- **Hybridisations**
  - Superposition of backscattering (if scatterer is not shadowed)
  - Incident field from asymptotic method
  - Backscattering interacts with the rest of the object
  - Full-wave formulation includes interactions with „exterior“ geometry

Hybridisation example: Dispenser Influence on RCS of transp. A/C

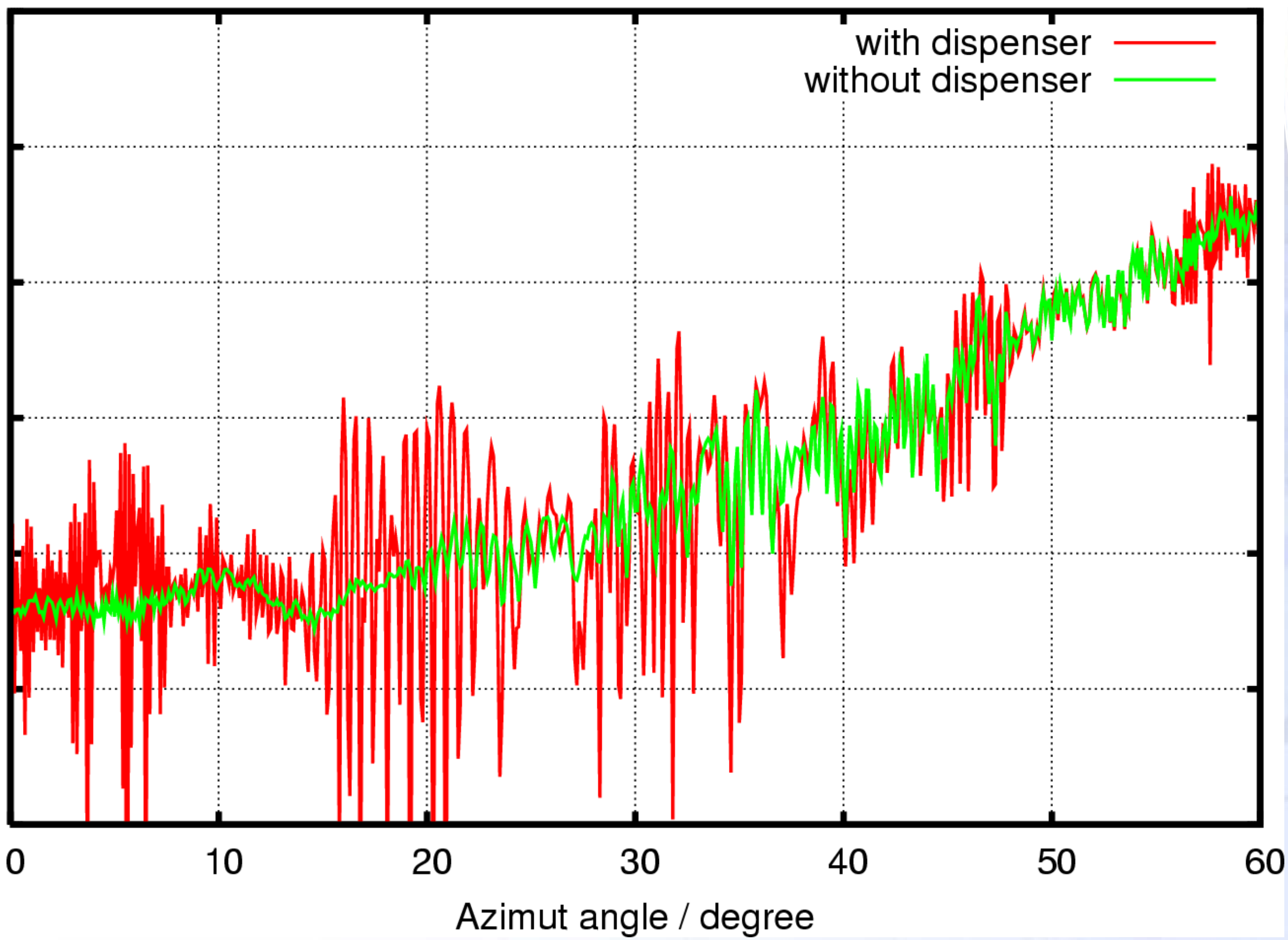
- Test section to evaluate influence of clustered dispenser compared with Fuselage return

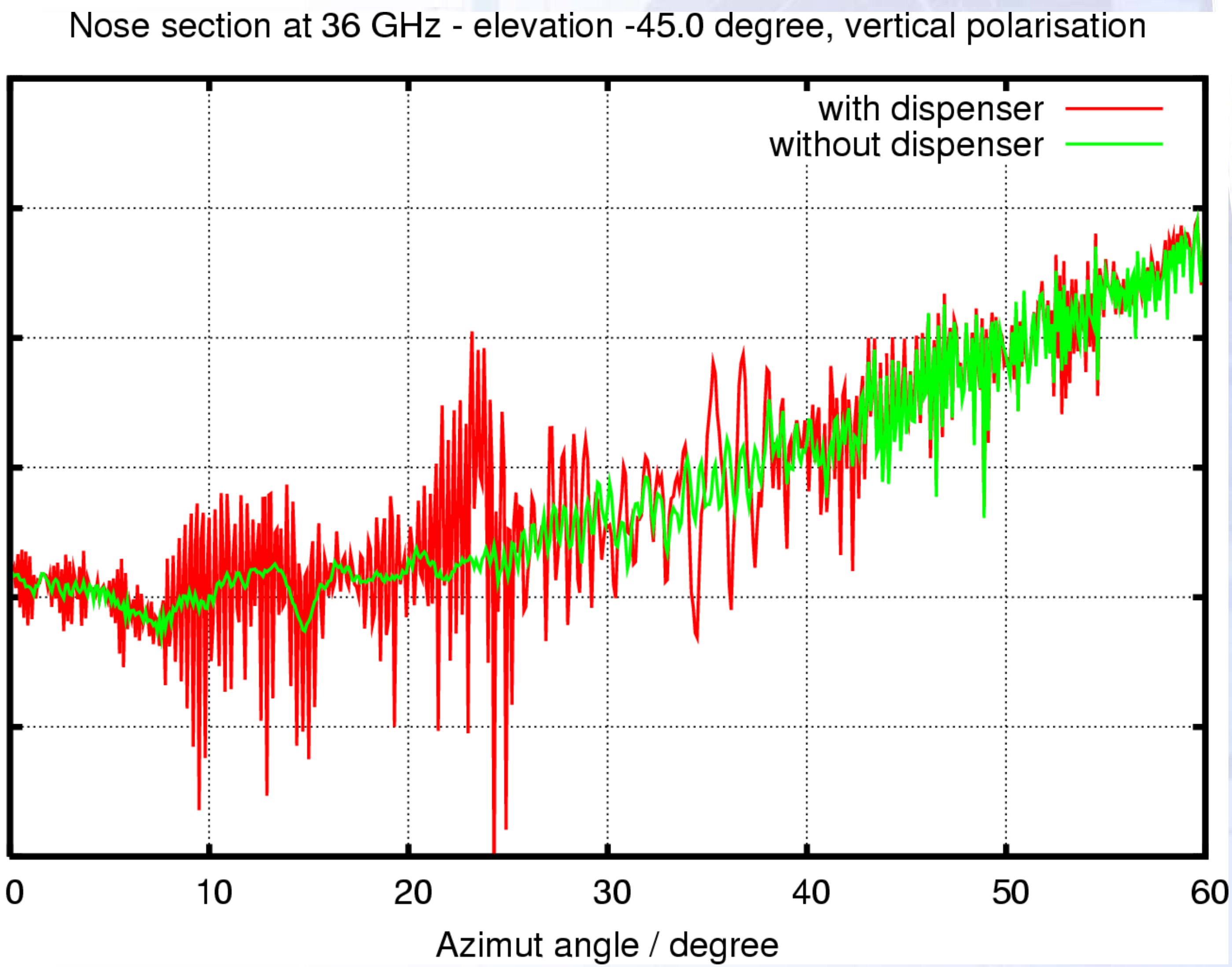






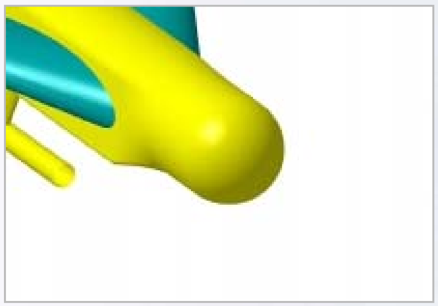
Nose section at 36 GHz - elevation -40.0 degree, vertical polarisation



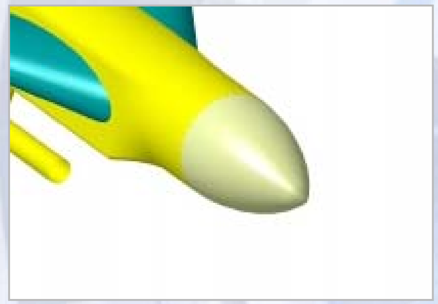

Nose section at 36 GHz - elevation -45.0 degree, vertical polarisation
with dispenser
without dispenser
0
10
20
30
40
50
60
Azimut angle / degree

Example for Full-Wave method / component analysis

- Example: bandpass radome (FSS) for radar application



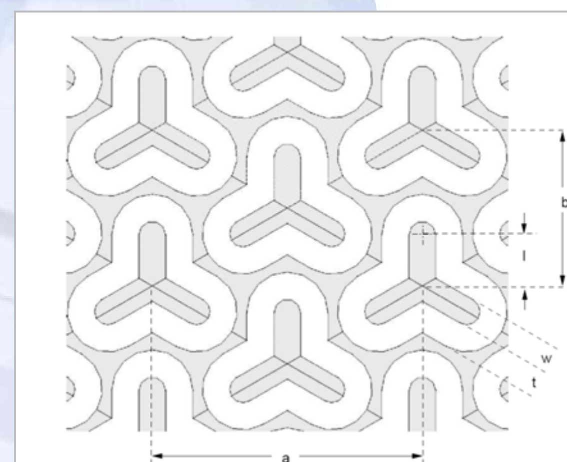
conventional



proposal with bandpass radome

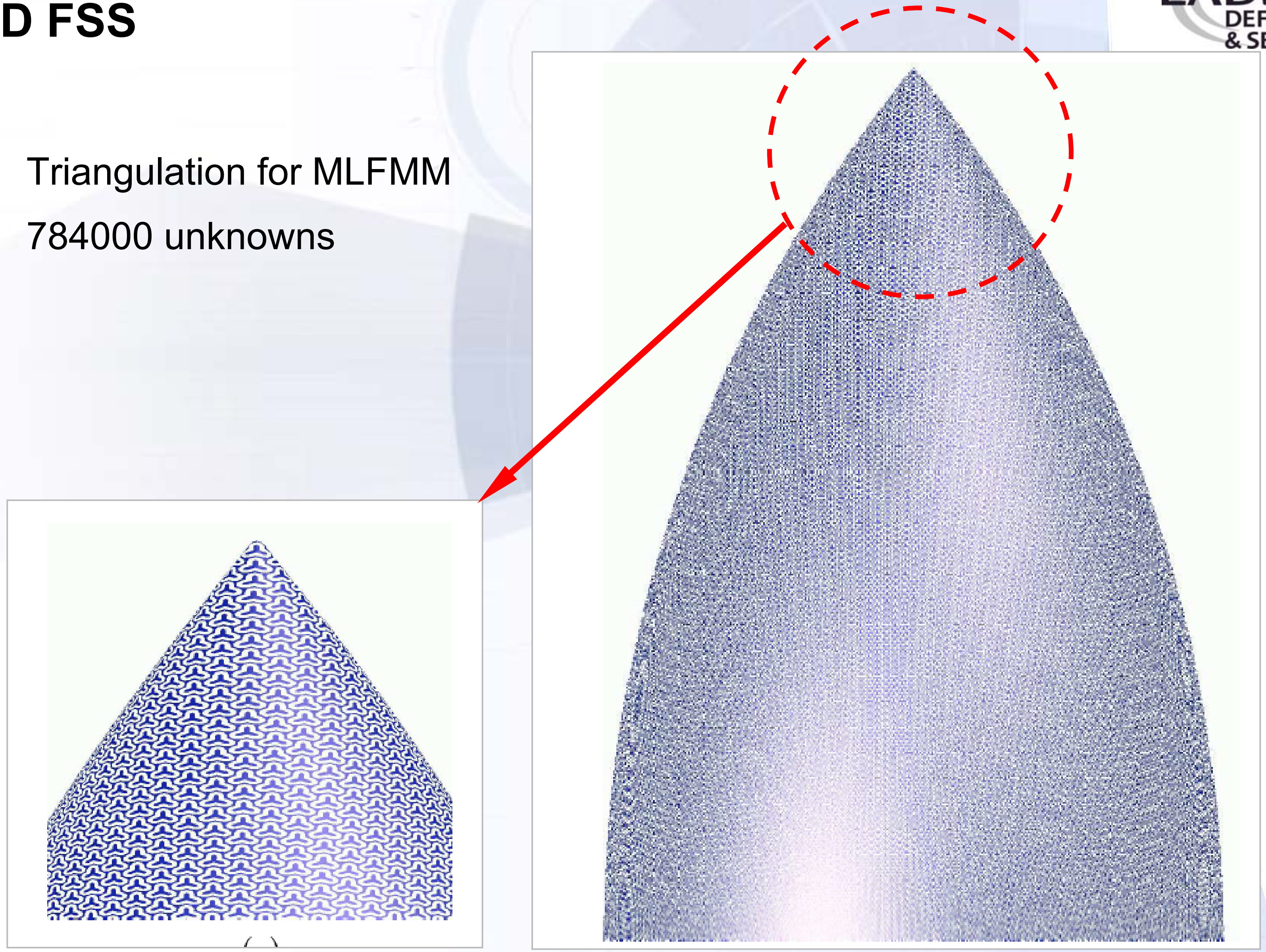
→ Detailed view of Bandpass structure:

→ Verification of 3D curved (ogive) bandpass

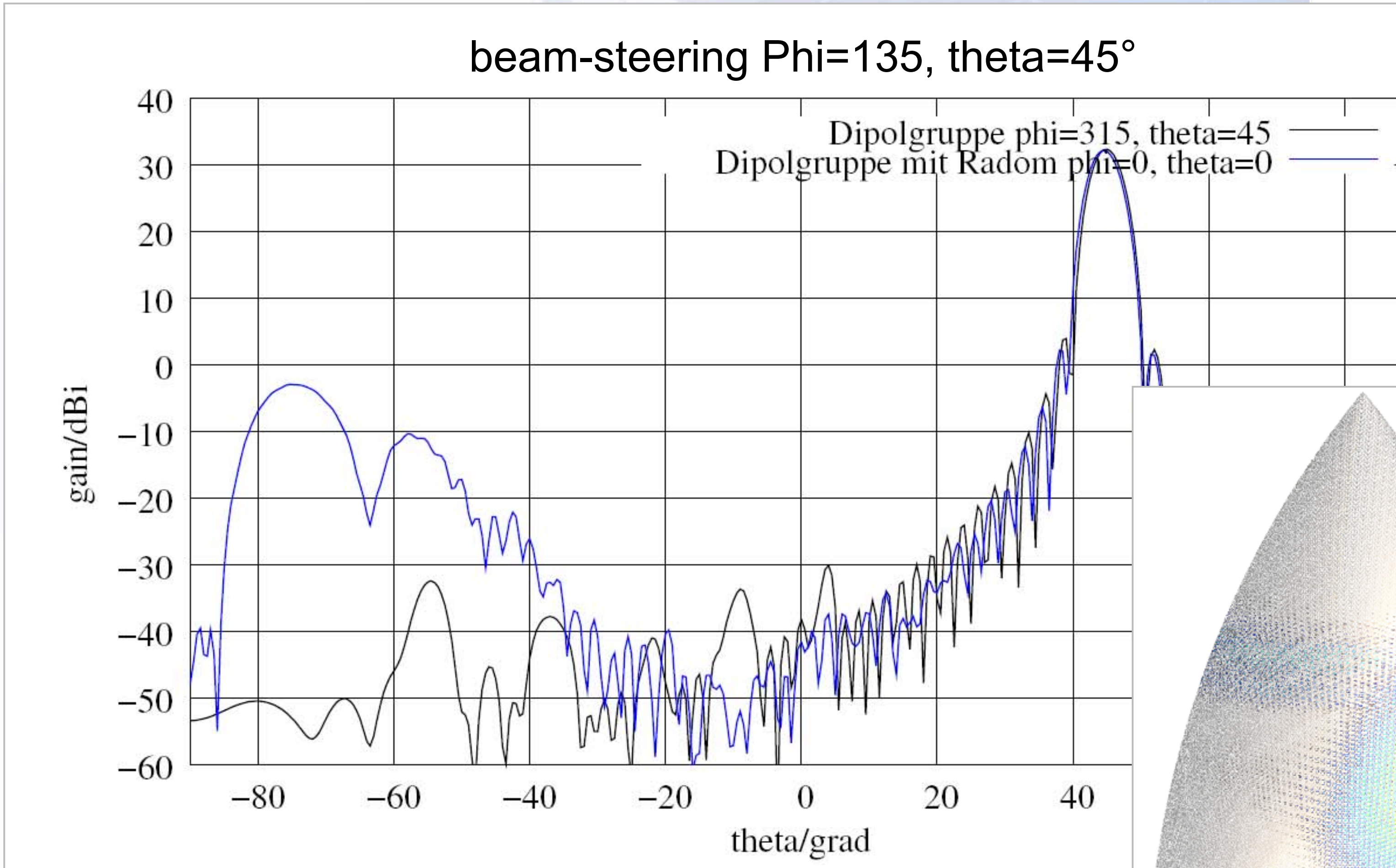


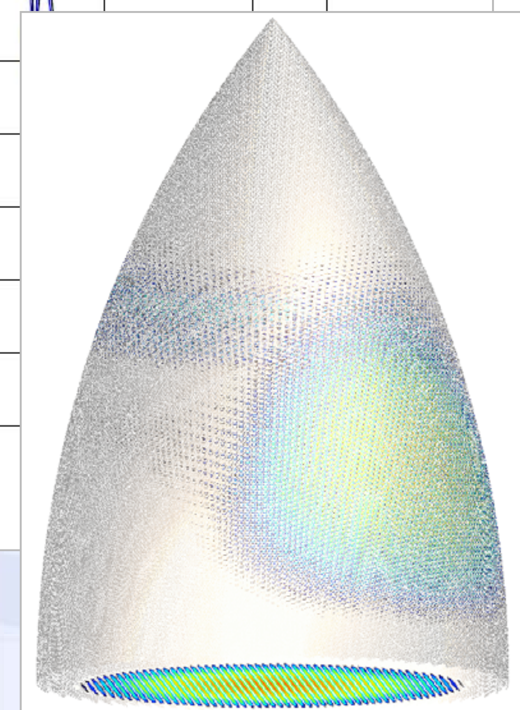
3D FSS

- Triangulation for MLFMM
- 784000 unknowns



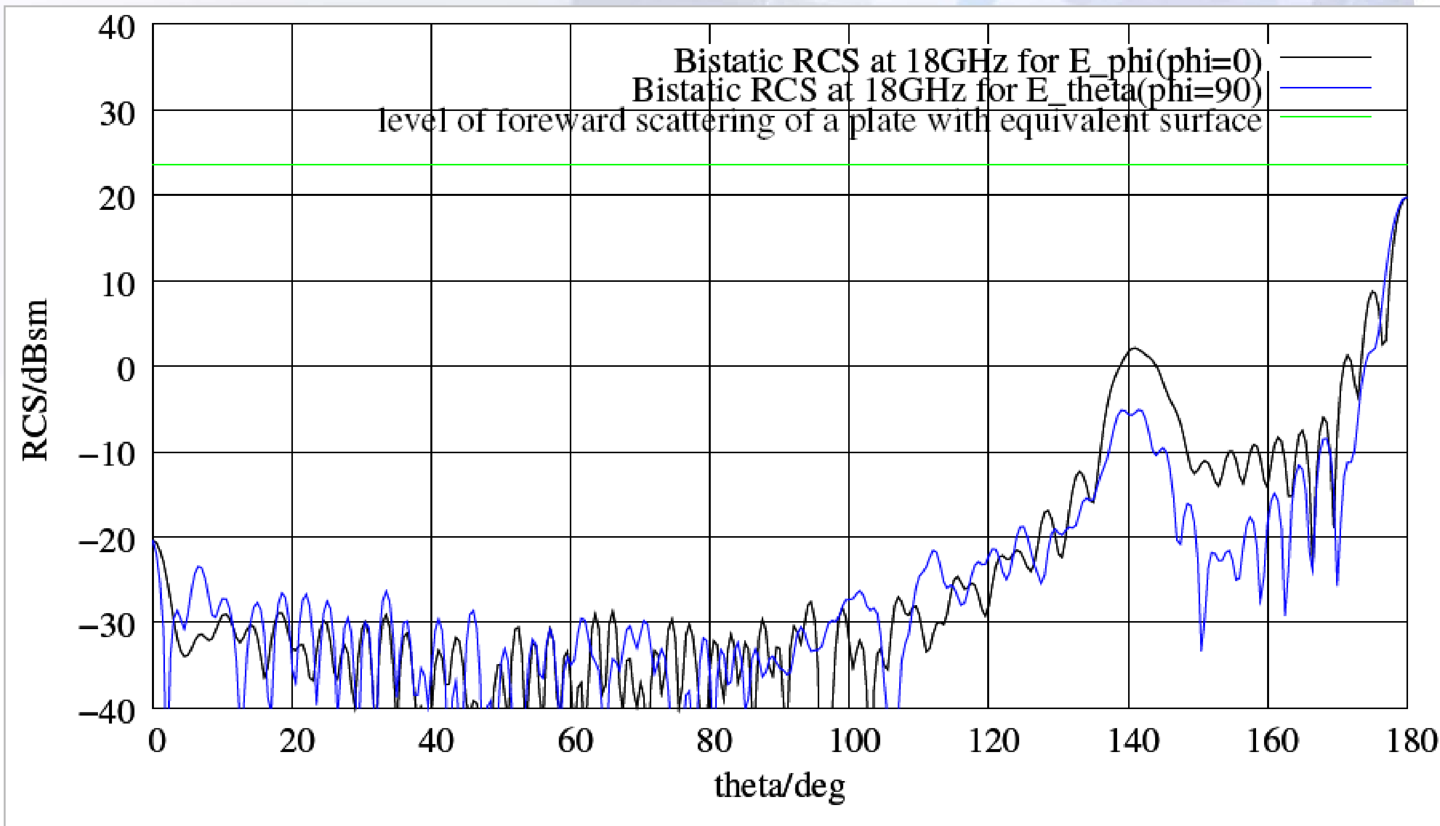
Performance / design verification of the Ogive FSS





RCS performance

- Bistatic RCS, front aspect

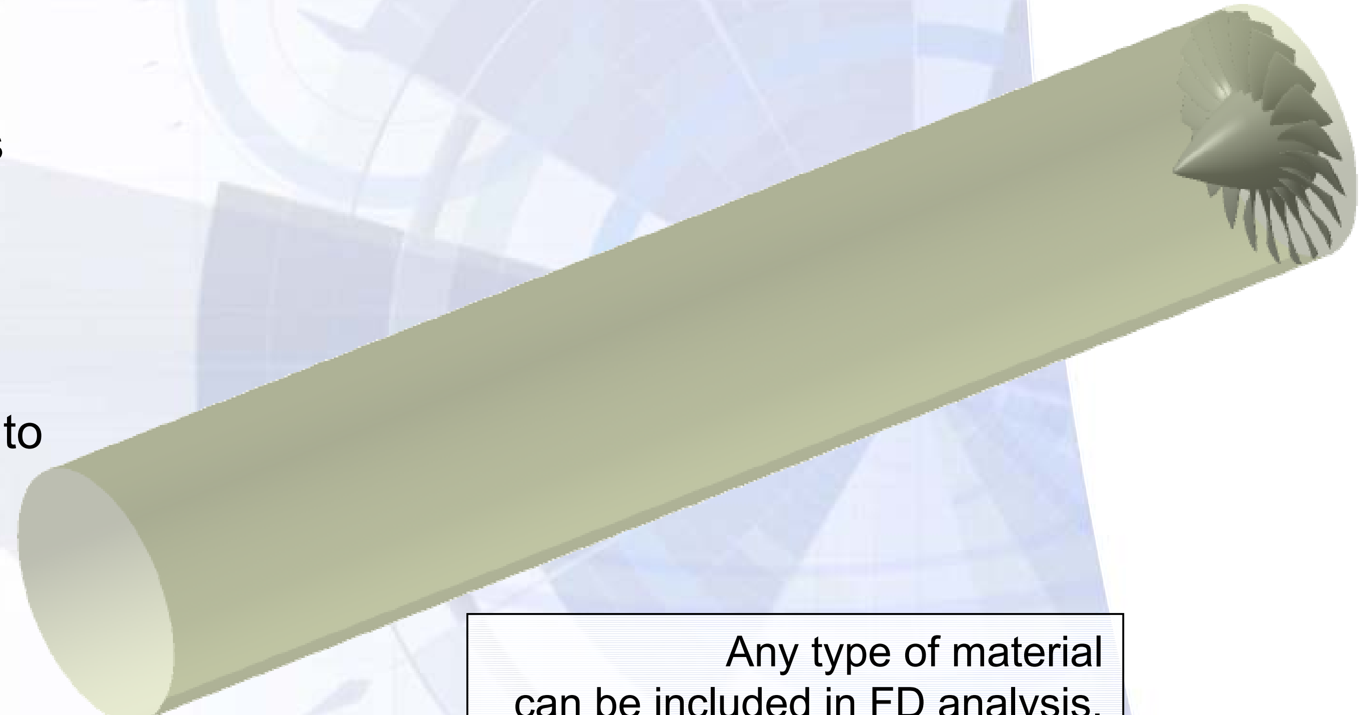


Finite Difference Code for large Engine Inlets

- Typ. application
  up to 400 mio. cells

- parallelized

- example: 4m Inlet,
  pulse-excitation up to
  18GHz



Any type of material
can be included in FD analysis.

Asymptotic Base-Algorithms

- For most A/C applications, 1st and 2nd bounce contributions are important (excluding cavities, inlets, etc.)

- Important: Algorithm should not scale with frequency

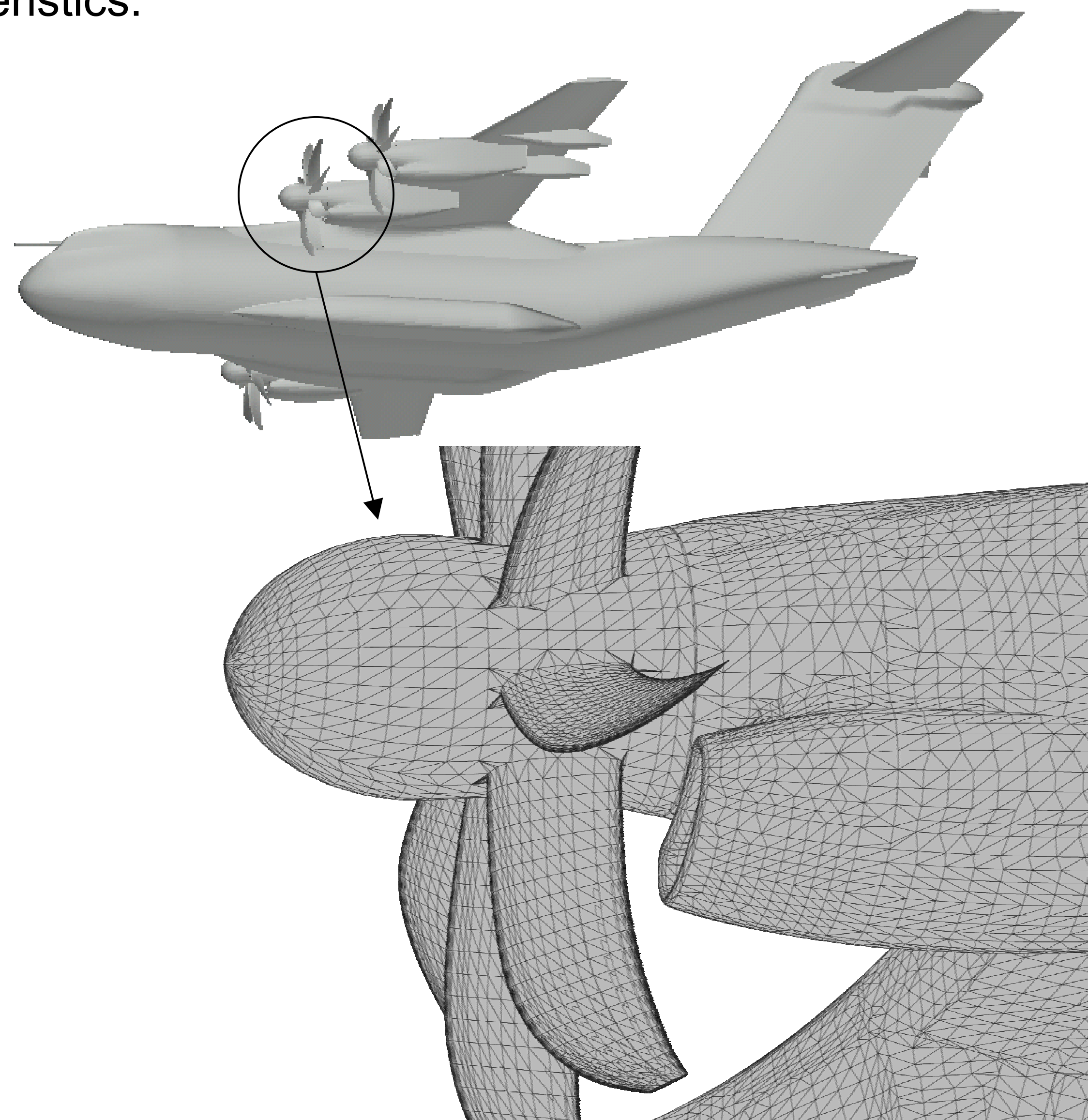
- Usual approach GO/PO for multiple effects.

  – PO scaling frequency independent;
  in practice: scaling by frequency dependent discretisation up to certain level.

  – GO (SBR) scaling due to ray grid density dependence from wavelength

Asymptotic Base-Algorithms – Physical Optics

- PROTHEUS / *RCSPO c*haracteristics:
  - Analytical integration of the PO-currents on plane triangles, typical object sizes: $10^5 \ldots 10^6$ triangles
  - Geometry: triangulation, triangle size depends on surface curvature. Deviations expressed in wavelengths (!)
  - *N* log *N* Algorithms for shadowing (plane wave, spherical wave sources)
  - Edge diffraction

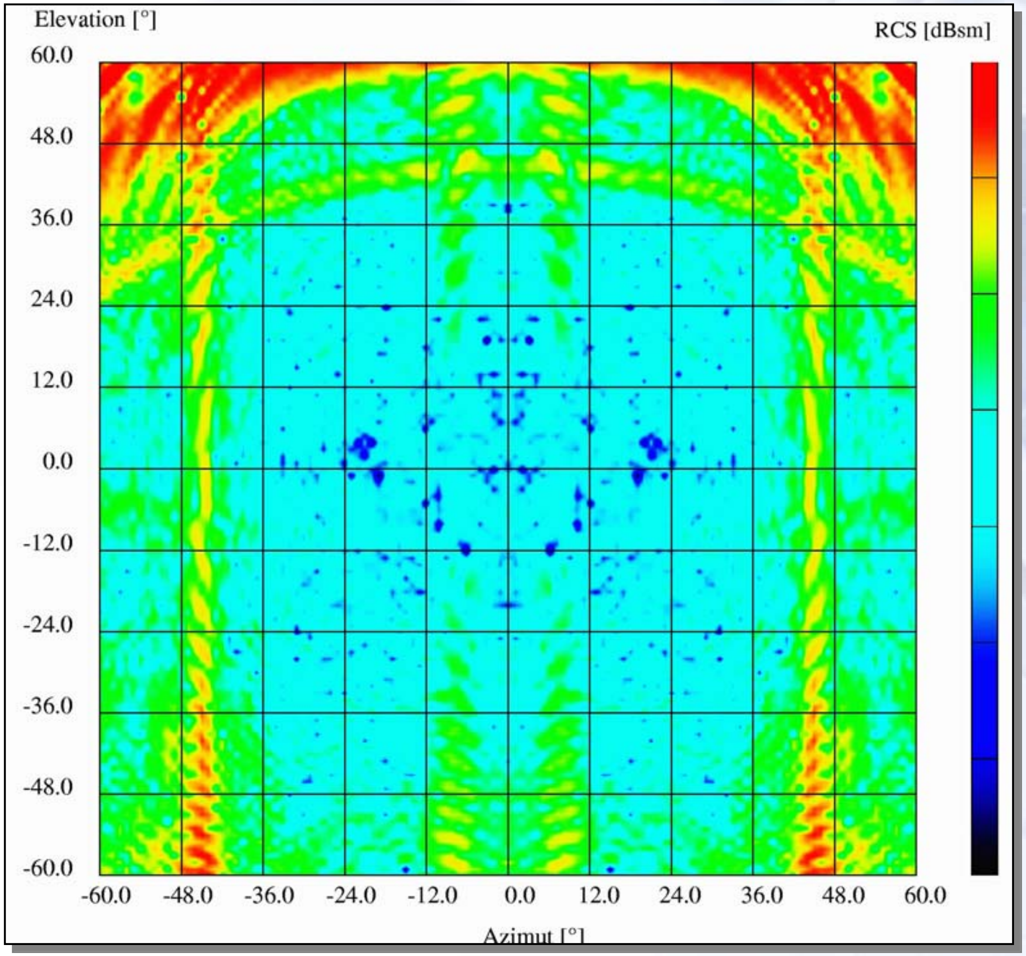


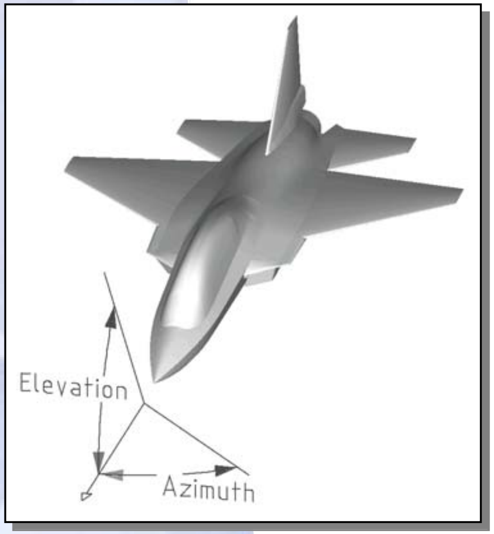
Asymptotic Base-Algorithms – Physical Optics

- PROTHEUS/ *RCSPO* characteristics:
  - **Efficient treatment of double reflections**.
    1. Frequency and incidence-angle independent pre-processing:
       - Generation of an interaction list (for domains on the surface)
       - Within the interacting domains, test for shadowing between triangles in the domains
       - Final determination of the coupling domains by various criteria.
    2. Within the frequency/angle loops: computation of the coupling between the pre-selected triangles.
       (N_d^2 process for N_d coupling triangles, but usually $N_d << N$)

Asymptotic methods for RCS evaluations

- Fast multi-aspect analysis using asymptotic techniques



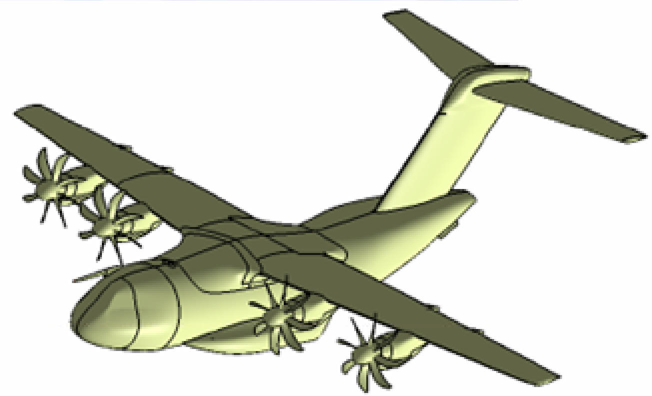


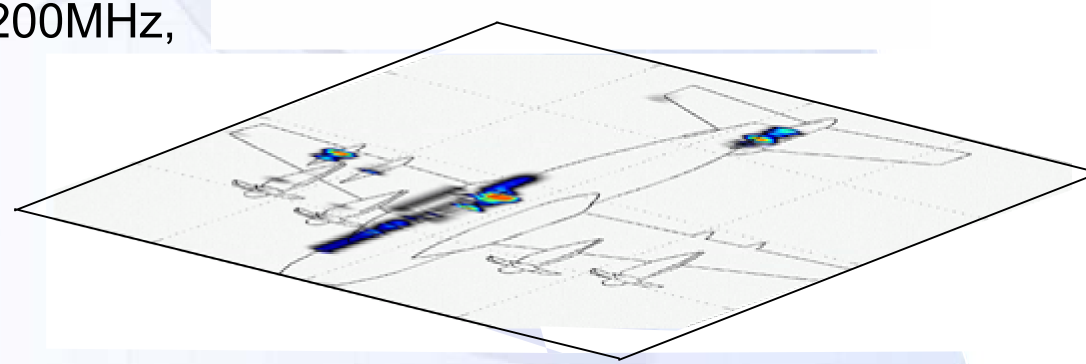
- This example: X-band, direct reflection, edge diffraction: less than 2s/angle 120*120 angles@20PCs: 20min

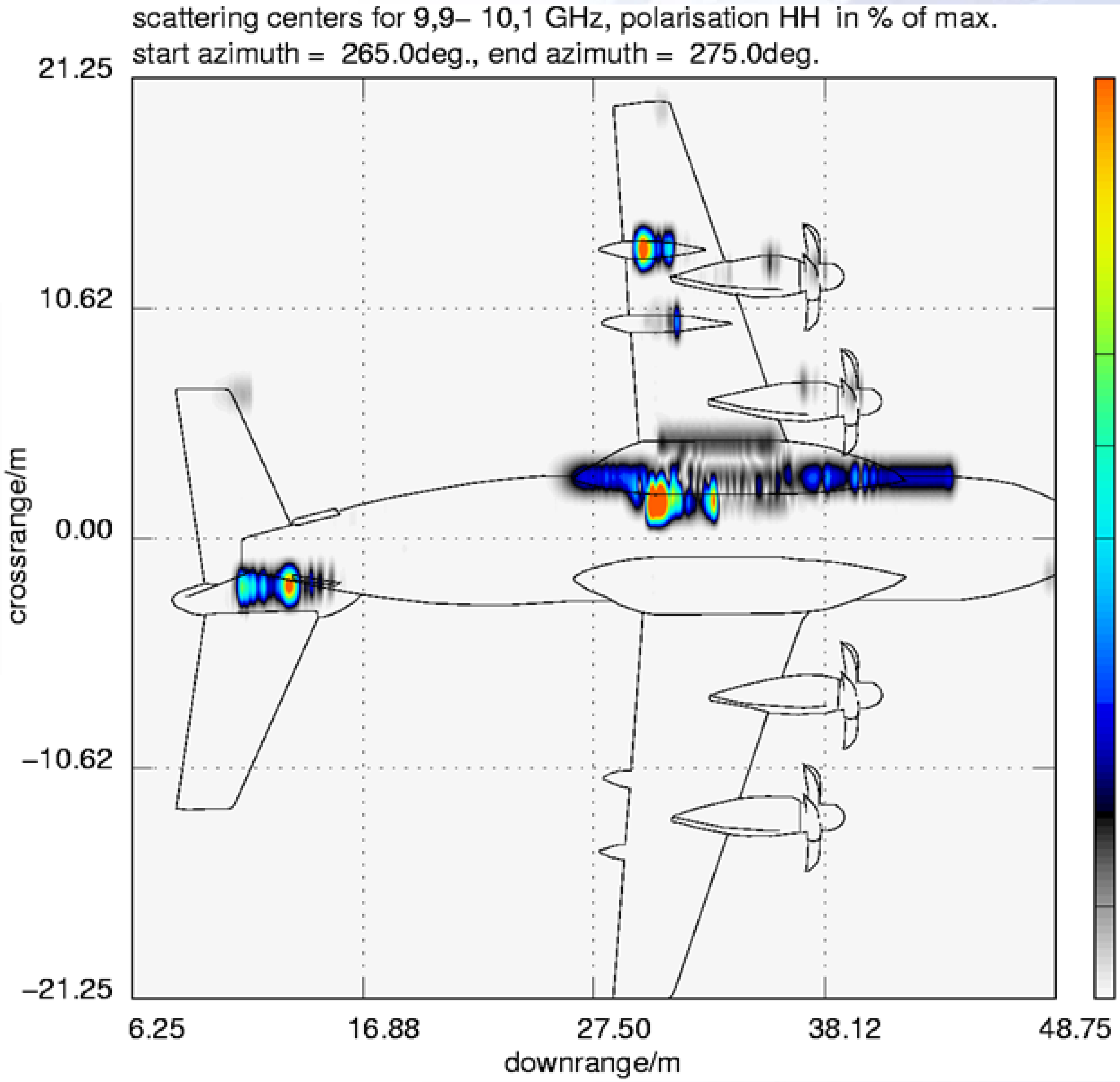
ISAR imaging

- Use of in-house developed imaging software (for RCS measurement post-processing)

- Generation of a 2D Image
  Example:
  Azimuth 90 +/- 5°, Elevation= -15°,
  Image-resolution 50cm:
  - Simulation bandwidth: 200MHz, step width 1MHz
  - Angular step = 0.0154°
  - 129600 simulations





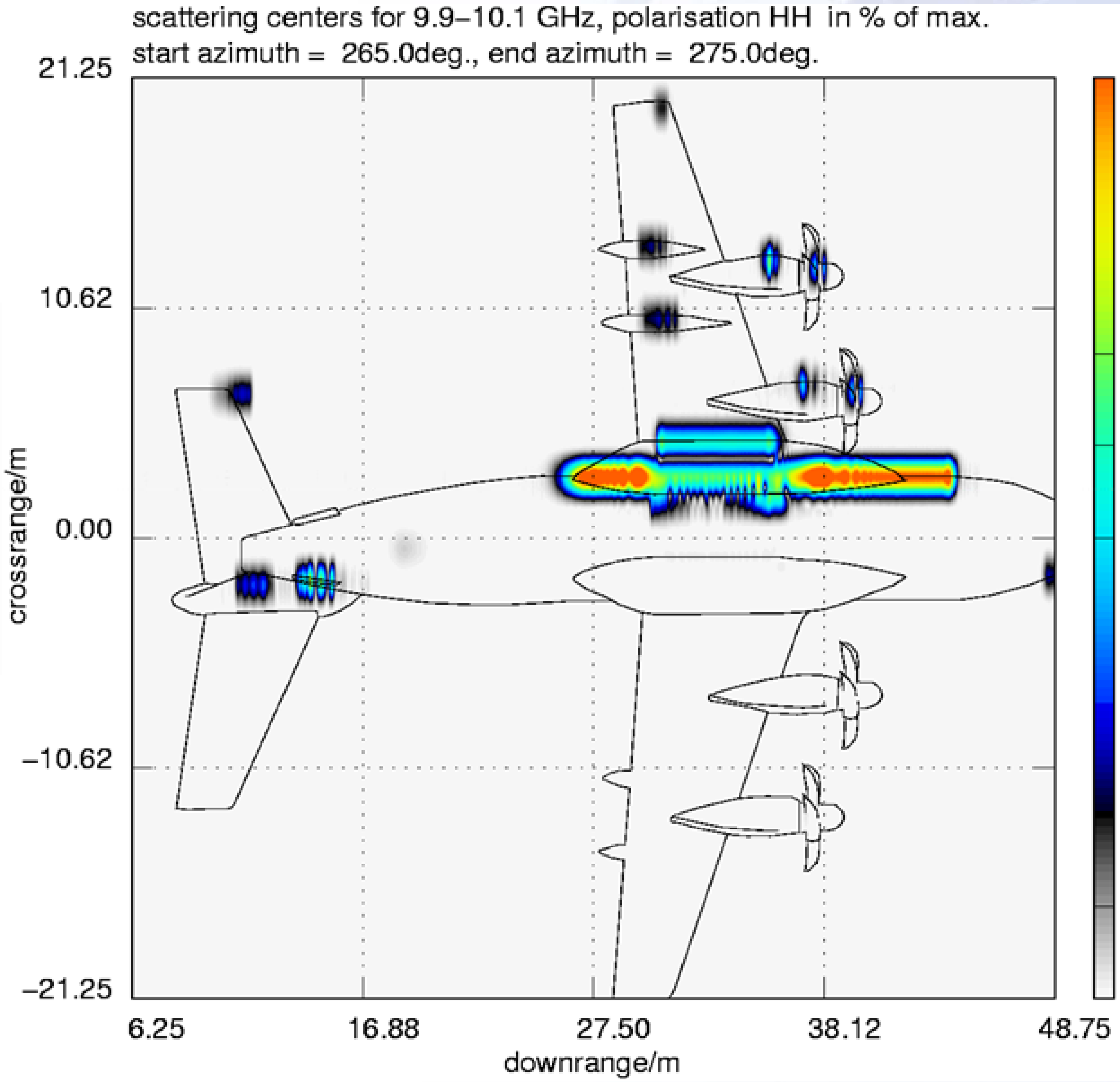


ISAR image

Elevation –15°

Azimut 85°-95°

All effects



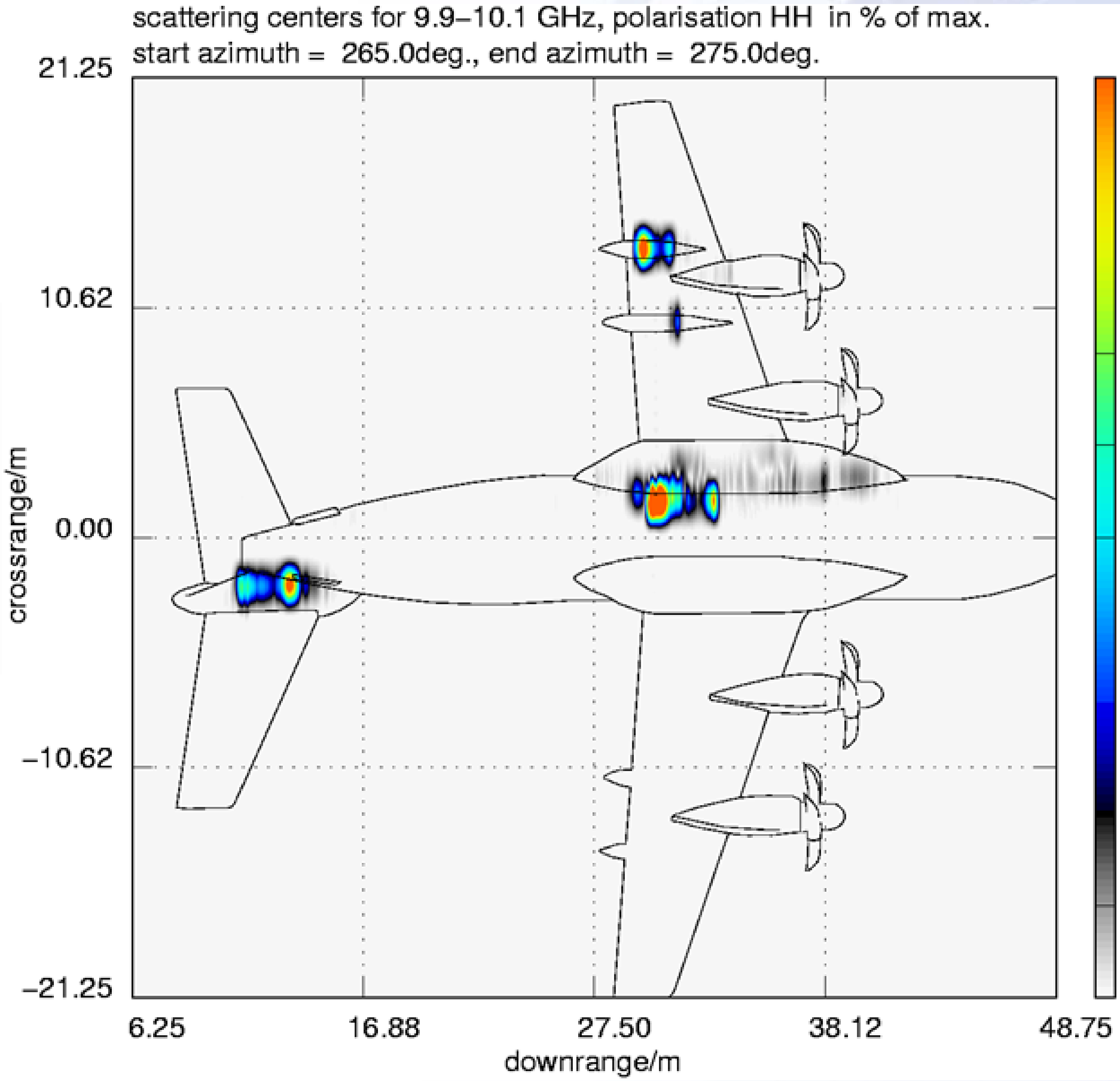
ISAR image

Elevation –15°

Azimut 85°-95°

Contribution:

Direct reflections



ISAR image

Elevation –15°

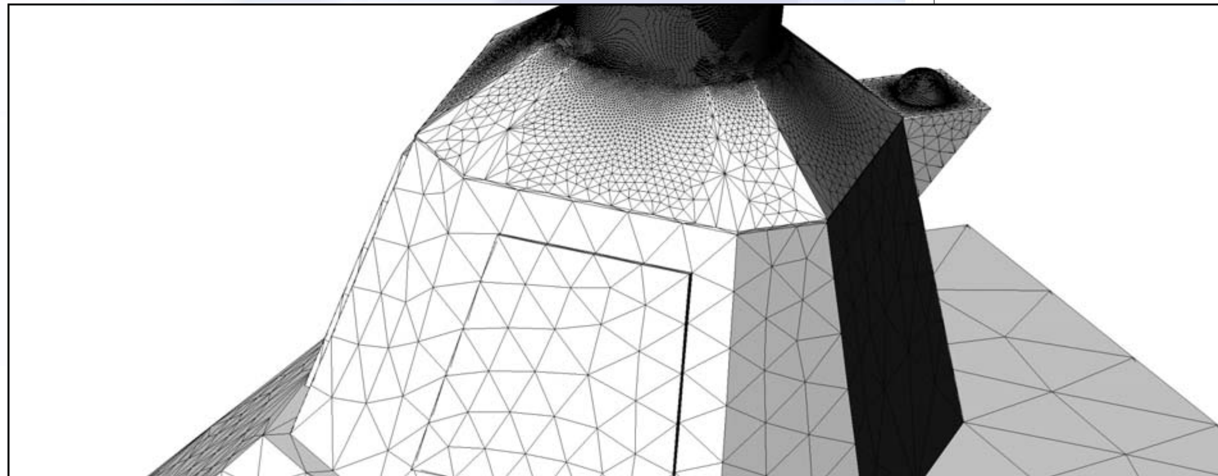
Azimut 85°-95°

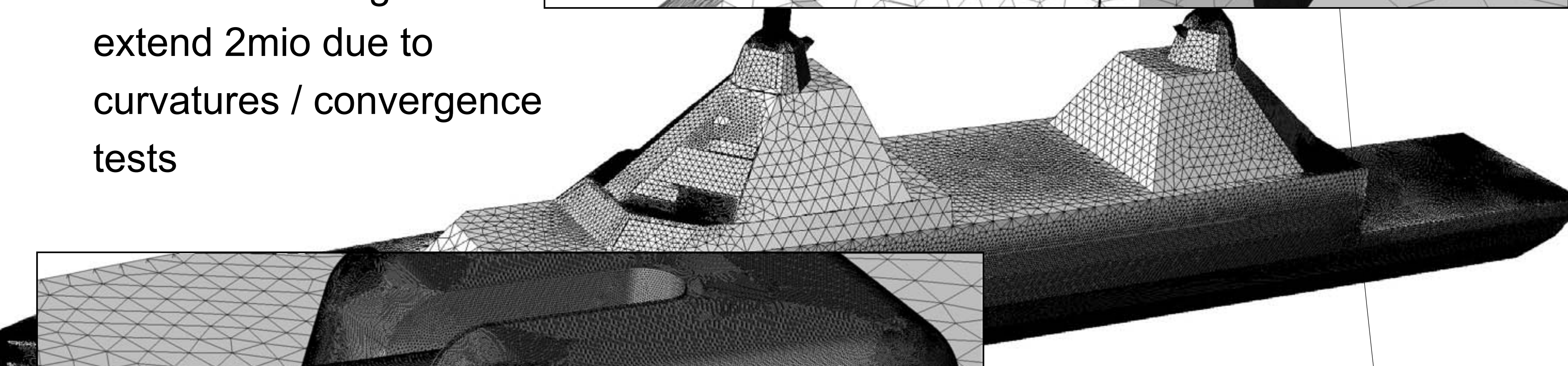
Contributions:

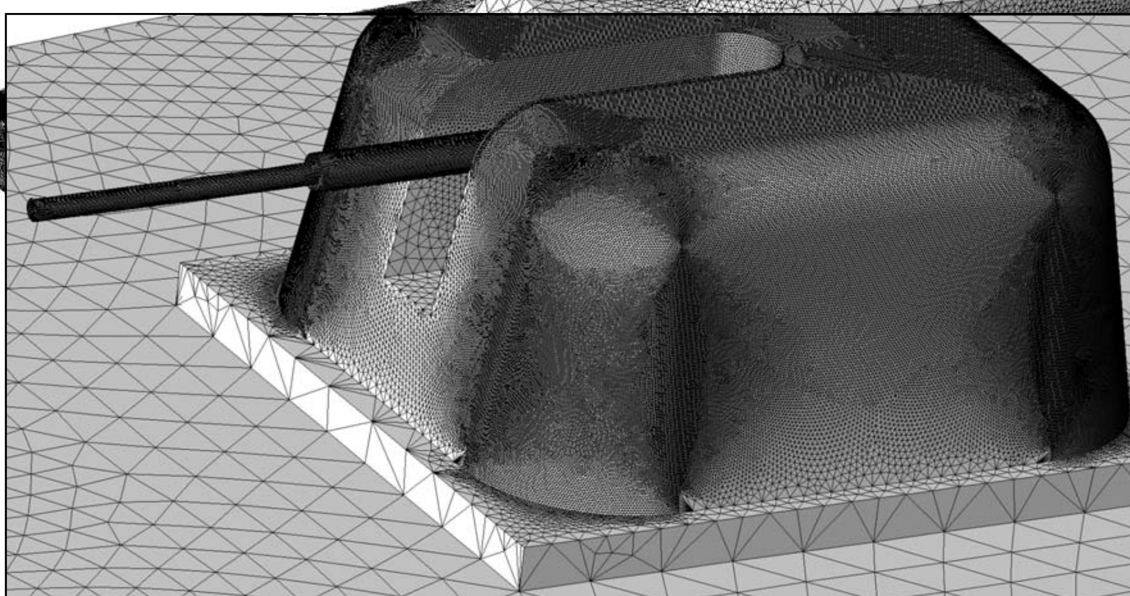
Double reflections

Current extensions

- Example: mesh of a ship config.
- Number of triangles extend 2mio due to curvatures / convergence tests







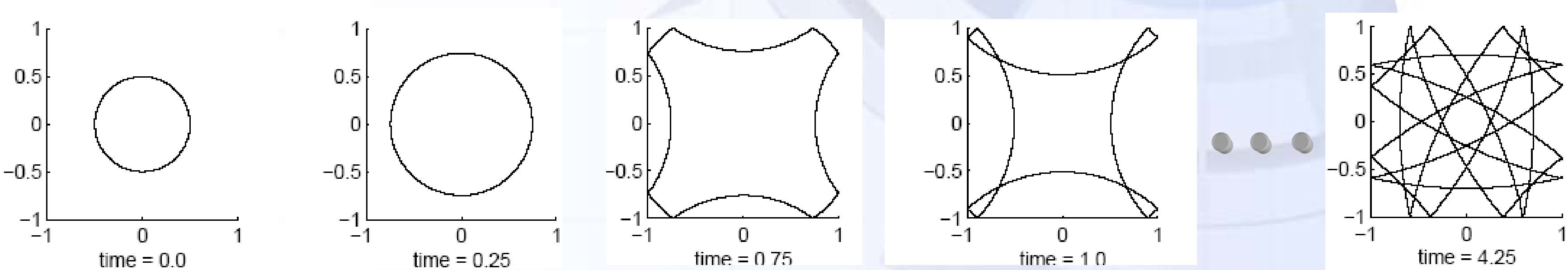
Extension to curved surfaces:

• NURBS handling to complex

• use curved triangles

Extension, Current Work

- Extension to curved triangles (polynomial up to 2.deg. in u,v)
  - Good compromise between number of elements, complexity of computation
  - Generation easy / wide spread available (used in visualisation)
- Totally frequency independent approach:
  - Investigation of the Wave-front (WF) evolution method



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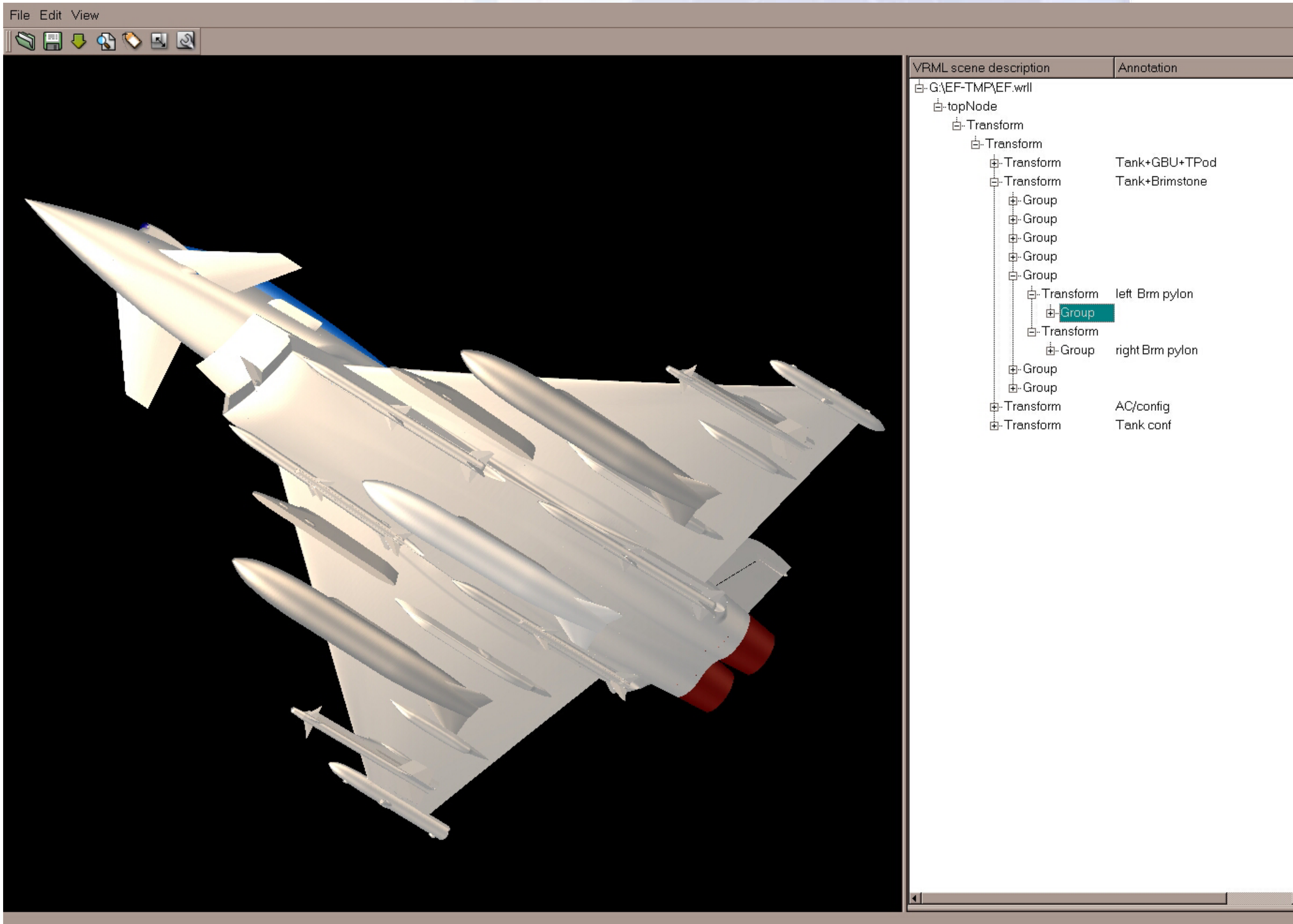
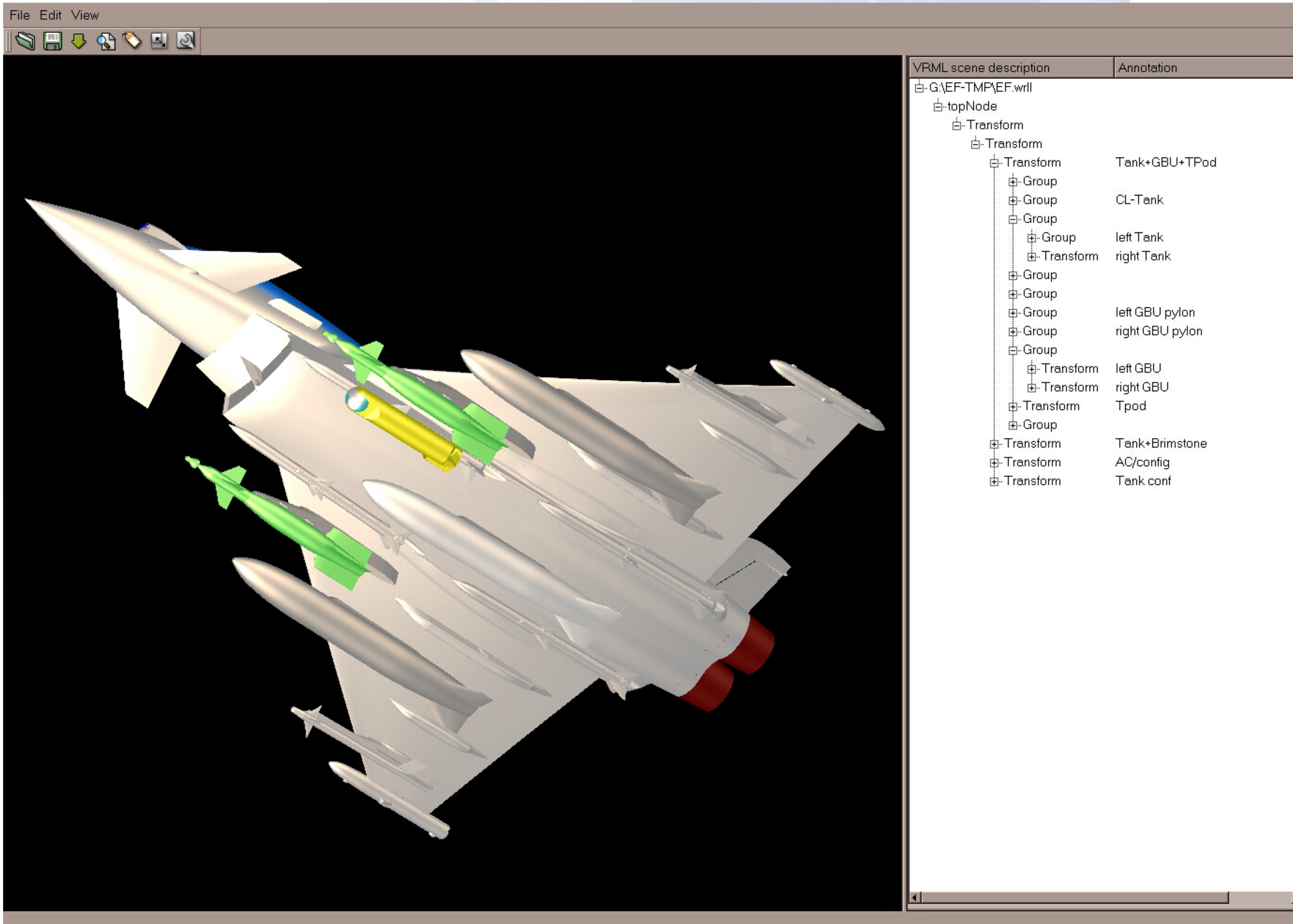
The CAD issue

- Requirements:
  - analysis of different vehicle-configurations (loads, stores, etc.)
  - Analysis of configuration in different states (moving parts)
- Modifications of the geometry in CAD is often time consuming
- We use VRML based geometry description
  - Meshed geometry, supporting also curved triangles
  - Widely available / incorporated in CAD systems,
  - Capable of keeping geometry data structure:
    - Enable / disable parts of the geometry
    - Parameterisation of transforms (moving parts) outside CAD

VRML based Geometry description



VRML based Geometry description



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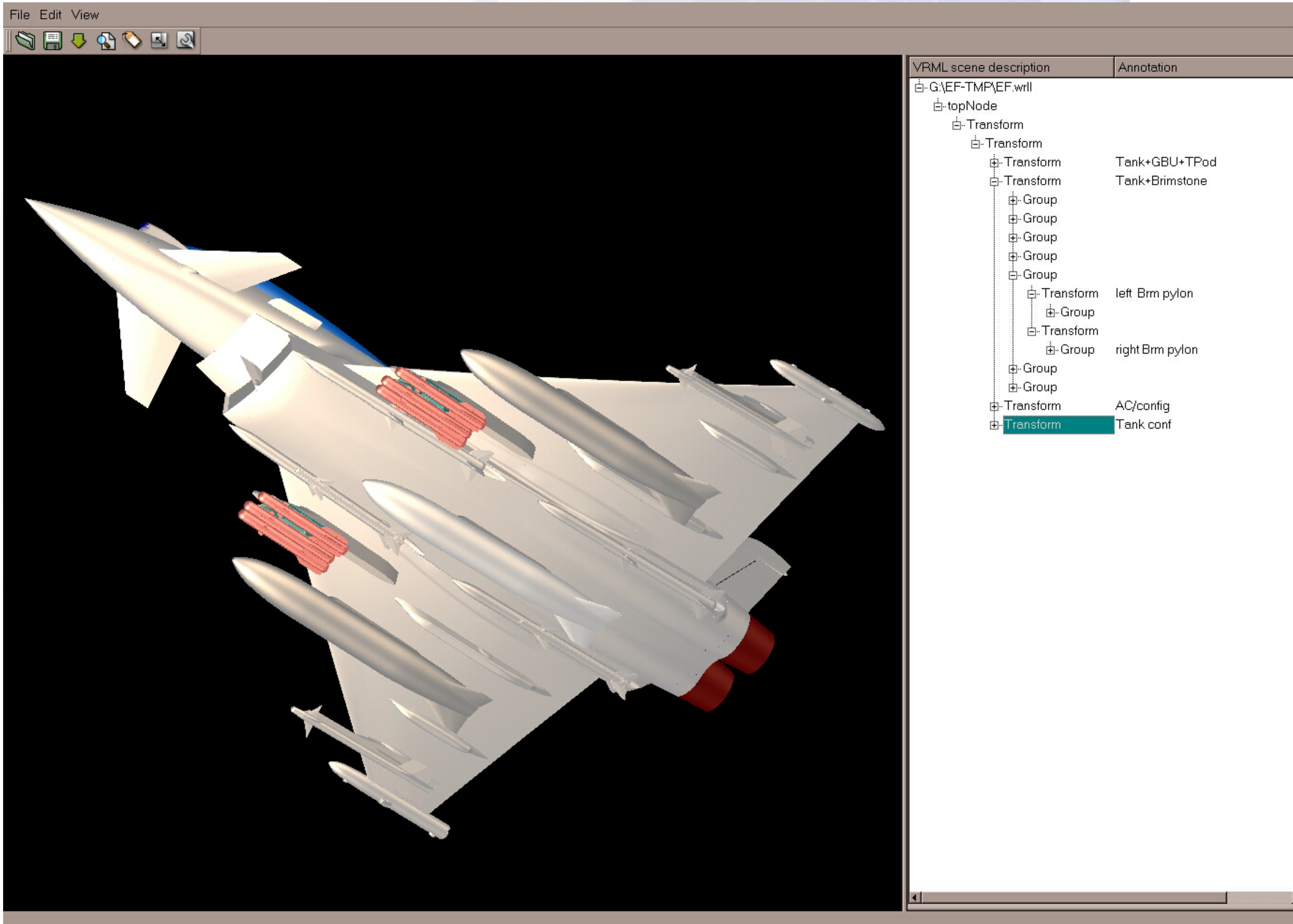

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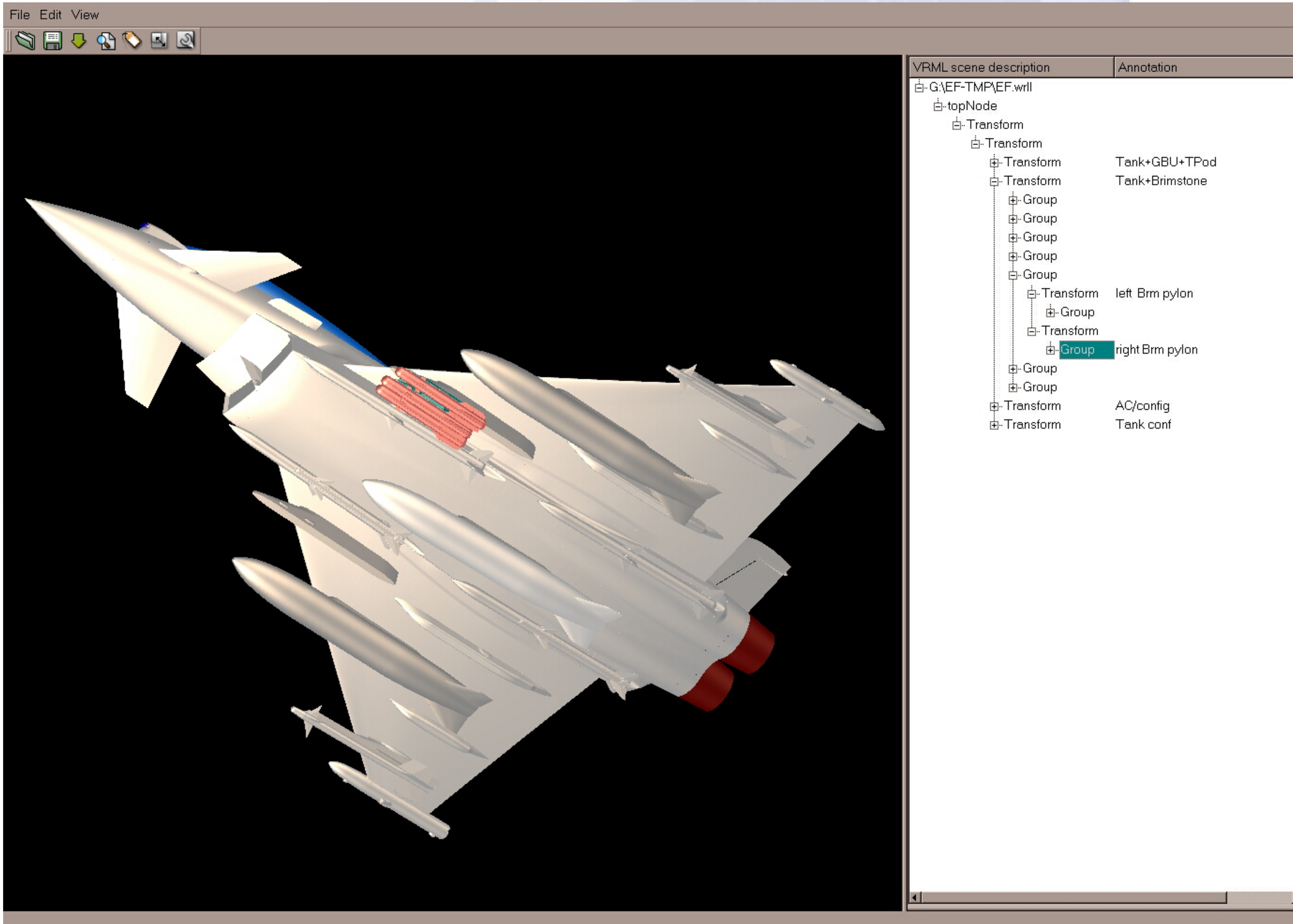

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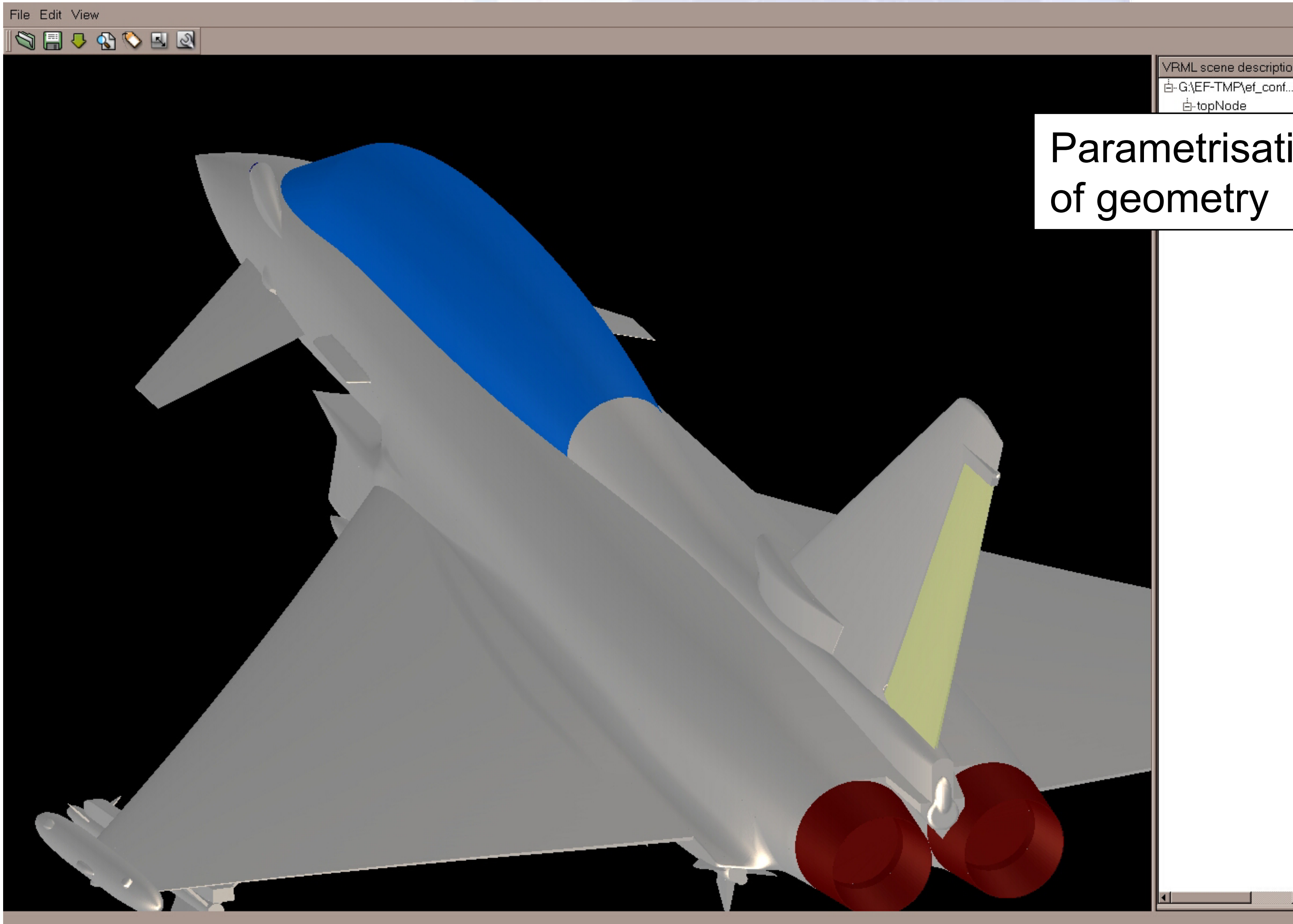
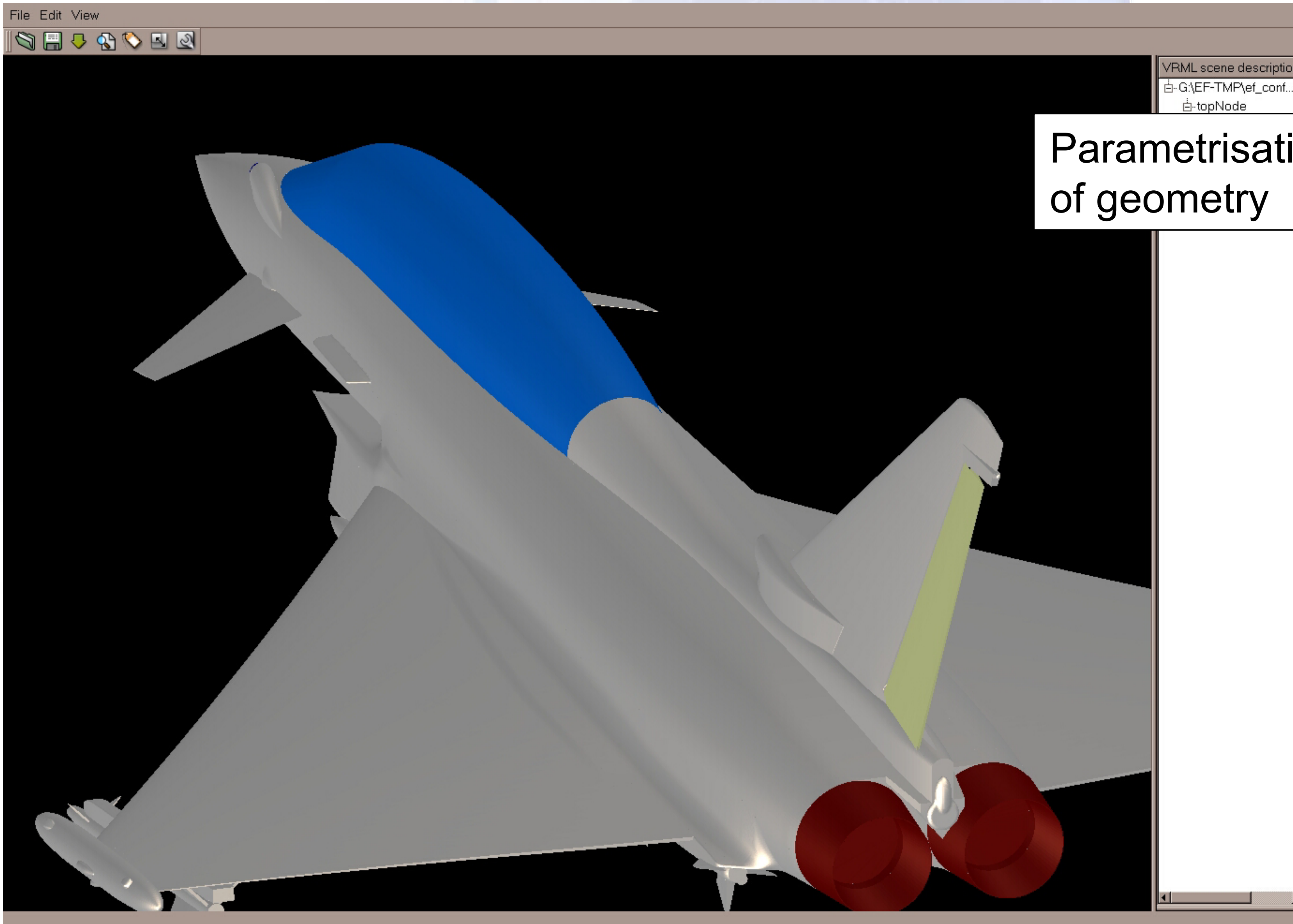


Parametrisation of geometry

VRML based Geometry description



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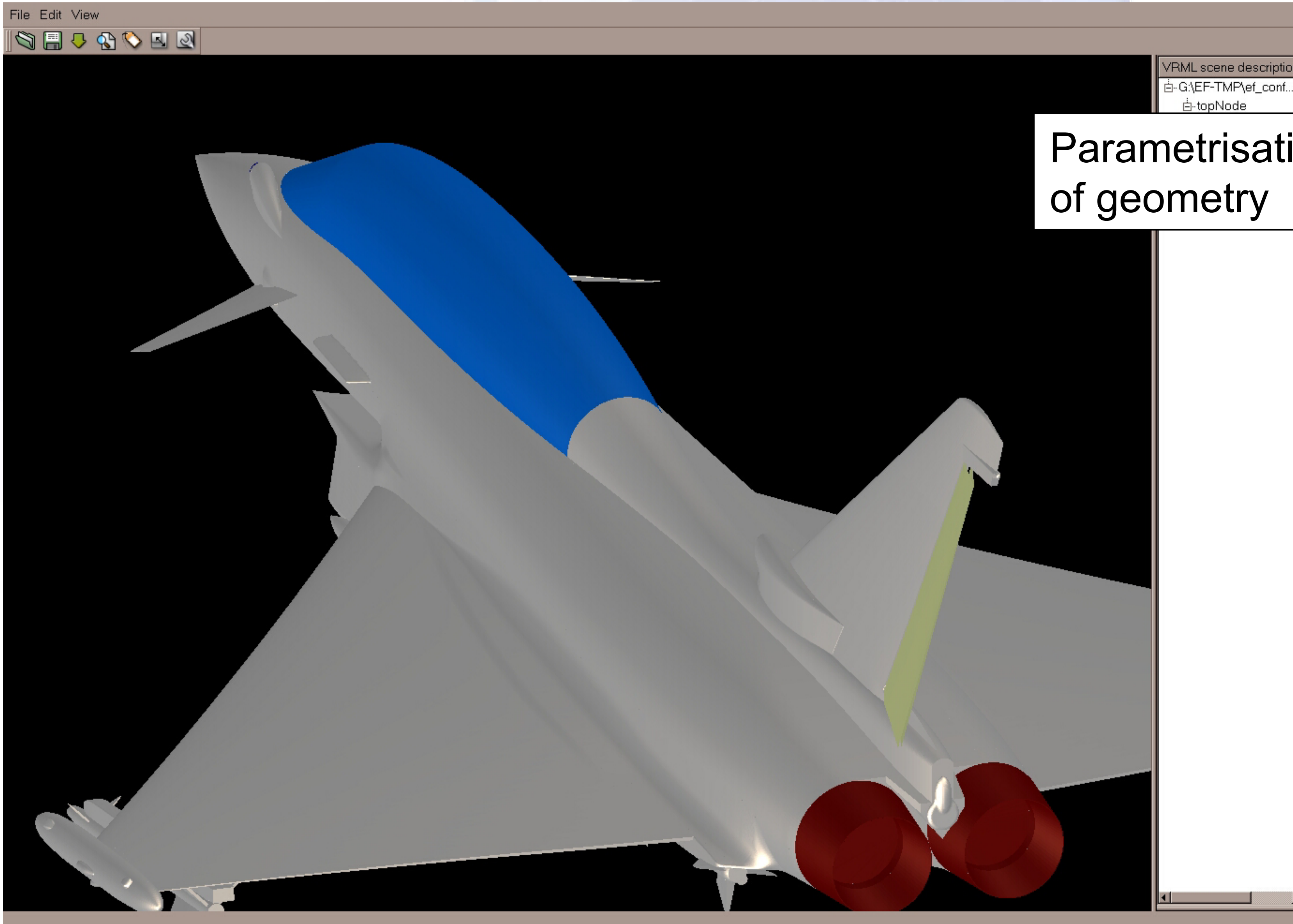
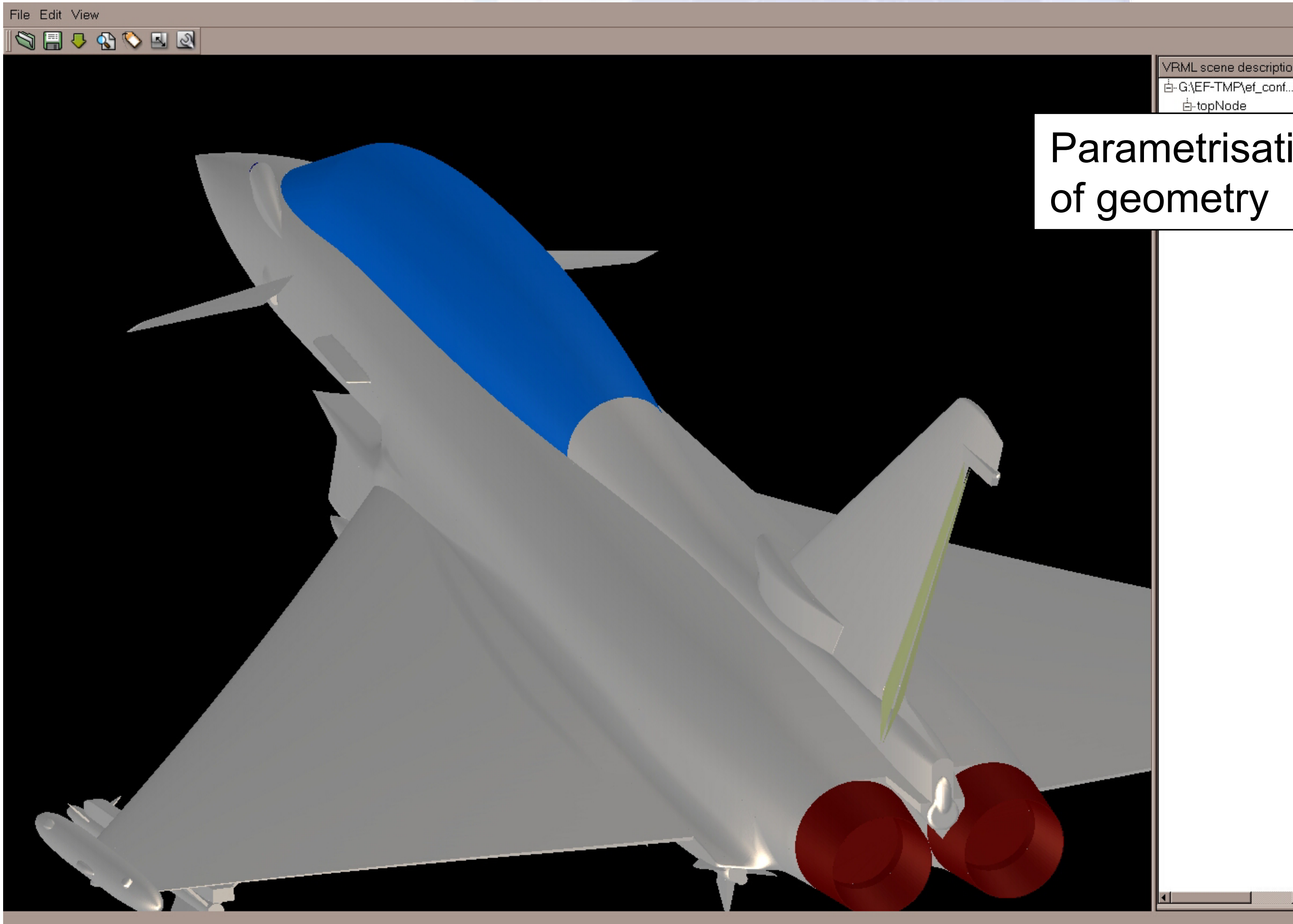


Parametrisation of geometry

VRML based Geometry description



Parametrisation of geometry

Conclusion

- Most of the realistic radar targets require hybrid method for simulation
- Even in mmw-applications, high performance full-wave tools are required for analysis of details
- Examples
- New developments, CAD issues, geometry handling

RCS Simulation

Jan Ritter
EADS Deutschland GmbH
Military Aircraft
MT67 – Signature
Technology
Huenefildstrasse 1-5
D-28199 Bremen
GERMANY

Jan.Ritter@eads.com

This paper was received as a PowerPoint presentation without supporting text.

Ritter, J. (2005) RCS Simulation. In *MMW Advanced Target Recognition and Identification Experiment* (pp. 15-1 – 15-2). Meeting Proceedings RTO-MP-SET-096, Paper 15. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

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